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ABSTRACT

This document provides an overview of the major research priorities of biotechnology and the use of what is known as "regrowing raw materials" in agriculture in the Federal Republic of Germany. Following an introduction, section 2 addresses biotechnology in agriculture, including biotechnology and genetic engineering, the significance of biotechnology in the agricultural and food sectors, new developments in plant breeding, examples of genetically engineered mutations in plants, biotechnology in animal production, and biotechnology and foodstuffs. Section 3 describes the state and future prospects of biological research and development West Germany, including main research centers and international cooperation. Section 4 explains the risks and dangers involved in genetic engineering and discusses the Genetic Engineering Act to become law on January 1, 1991. Section 5 explores the future prospect of "regrowing", i.e., renewable, materials. Section 6 discusses industrial uses of regrowing raw materials, including nonpolluting natural oils and fats, starch, sugar, plant fibers such as flax, and wood. Section 7 addresses regrowing raw materials as energy sources, including alcohol that is fit for transport, vegetable oils as fuels and lubricants, and heat and electricity produced from biomass for developing countries. Section 8 considers the future development of regrowing raw materials. The document concludes with addresses of relevant ministries and research institutes in West Germany and a bibliography of seven resources written in German. (CML)

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Agriculture Breaks New Ground

– How biotechnology and regrowing materials are being used in the Federal Republic of Germany –

by

Fritz Grimm and

Sigrid Born

U.S. DEPARTMENT OF EDUCATION
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1. Introduction

Biological processes have been used in agriculture for centuries to secure and increase crop yields, and to augment the availability of food. New findings in all areas of science and the rapid development of basic knowledge on life processes, molecular genetics and cytobiology have, in the meantime, opened up many new opportunities for agriculture and the food industry.

In plant breeding alone, the employment of biotechnical methods has made a large measure of innovation conceivable, including, for example, an improvement in reserve-substance production (sugar, starch, oils, fats, protein) or enhanced resistance to disease which reduces the use of environmentally harmful plant protection products.

Highly productive, healthy varieties, and those particularly suitable for industrial processing, also favour, medium and long-term, the use of what are known as "regrowing raw materials". The latter are basic materials for the industrial sector, which are regarded as particularly non-pollutive and which, by way of a precaution, reduce the exploitation of fossil raw materials such as mineral oil and coal. Plants can be combusted, entirely or partially, to produce energy, or be converted into fuel or biogas. Admittedly, compared with petrochemical products, regrowing raw materials offer little or no competition at the present time.

This paper is designed to provide an overview of the major aspects and research priorities of biotechnology and regrowing raw materials in agriculture in the Federal Republic of Germany.

2. Biotechnology in agriculture

Plant breeding, up to 200 years ago, was carried out with the repeated selection and cultivation of suitable plants. The cross-breeding of individuals, with their differing properties, was not used as a breeding method until a much later date. The first cross-breeding experiments were carried out around the turn of the century when the significance of Austrian Gregor Mendel's (1822-1884) laws of heredity was universally acknowledged.

The majority of plant varieties cultivated today are the result of cross-breeding undertaken in the last five decades - a process in which the combination of crossing and selection is still the predominant feature.

Of late, however, scientists have been by-passing the tedious cross-breeding process by systematically transferring the genes of one plant into the cells of another. From these cells, it is then possible to regenerate plants with the desired combination of features.

In other words, "classical" biotechnology is based on the optimization of plants through selection and mutation - a process in which the element of chance by no means plays an unimportant role. Scientists have meanwhile gone on to deciphering the available hereditary information on a molecular basis, isolating genes with specific information, and infiltrating it into another plant.

Plant reproduction aside, biotechnology is also of major importance in the fields of animal production, regrowing raw materials and food production.

The rapid development of basic knowledge on life processes, the findings in molecular genetics and cytobiology are opening up numerous new possibilities in

- agriculture and the food industry,
- plant protection and veterinary medicine
- the provision of biogenetic raw materials and the manufacture of high-grade natural products and
- environmental conservation.

Far-reaching progress in the biosciences - primarily in the fields of molecular-biological, basic research, microbiology, biochemistry and biological process engineering - give rise to the expectation that, by means of purposeful, genetic intervention and control, these systems can be used with considerably increased efficiency.

Biotechnology and genetic engineering

Biotechnology and genetic engineering are not necessarily one and the same thing. "Biotechnology" usually means the control and exploitation of biological systems for the systematic production of substances. "Genetic engineering", according to Ignaz Kiechle, Federal Minister of Agriculture, at the International Forum of Agricultural Policy of the German Farmers Association in 1989, "is, in essence, a special area within umpteen new processes which come under the general heading of 'Biotechnology'. In this context, genetic engineering offers the greatest opportunities of specific mutations in hereditary material and intervention in biological systems."

These developments have meantime attracted international attention even if the application of biotechnological techniques on a broad basis has been crowned with success in only a few areas and their economic employment in agriculture and the food industry is still in its infancy. Be that as it may, it can be assumed that - like micro-electronics - biotechnology represents a key technology within the ongoing industrial and technological development of the future. This assumption is also the reason why research projects in this field are being particularly promoted in industrialized countries.

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Biotechnological research is also being heavily promoted and increasingly expanded in the Federal Republic of Germany. The responsible authority, the Federal Ministry of Food, Agriculture and Forestry which, together with the Federal Ministry of Research and Technology, is carefully following developments, states in this connection:

> "Agricultural policy will have to exert its influence on the entry of biotechnology into agriculture and the food industry to exploit the opportunities of enhancing the efficiency and competitiveness of the agricultural and the food sectors through biotechnical innovations and to create politico-agricultural measures in the service of the public more effectively. In this context, it has to rely on analyses and evaluations of the state-of-the-art in biotechnology and must give due consideration to the effects on politico-agricultural, economic and social objectives, questions of safety and ethical problems. The benefits offered by biotechnology will be all the greater, the better we succeed in promoting coordinated and purposive technological development."

There is no doubt about the fact that biotechnology and, in particular, genetic engineering methods, are opening up great possibilities. But they also involve risks and elements of uncertainty. As a consequence, the German Federal Government has resolved to draft a genetic engineering bill.

The significance of biotechnology in the agricultural and food sectors

Biotechnological processes have a number of advantages over conventional ones, such as chemical methods, since they take place largely under natural, enviromental conditions. They can be more economical in regard to energy consumption and raw-material exploitation - and of greater benefit to the environ-

ment - compared with conventional techniques. The multiplication of plants on the basis of cells or tissue sections, for example, and their regeneration into whole organisms, take place considerably faster than by sexual means - whereby breeding progress can be speeded up and costs reduced.

Biotechological methods are employed, for instance, for

- breeding existing and new, cultivated plants,
- assuring the yielding capacities and powers of resistance in useful plants,
- improving breeding methods,
- improving animal health,
- enhancing the quality and imperishability of foodstuffs,
- reducing noxious and waste substances in environmental conservation processes,
- developing medicaments, vaccines and diagnostic agents,
- converting raw materials.

The Cologne-based Max Planck Institute of Breeding Research is playing an important part in the field of research in the Federal Republic of Germany. Professor Heinz Saedler, director of the Institute's department of molecular phytogenetics, gives a graphic description of the state-of-the-art in biotechnical plant breeding when he writes:

> "When visiting the weekly market nowadays, one sees a colourful variety of plant products: lettuces of all shapes and sizes, apples, vivid green to wine-red, catering for all tastes, a wide selection of cabbages - from savoy to broccoli - and numerous varieties of potatoes offering differing qualities for diverse culinary requirements. Compared with the wild species, to which they owe their origin, modern cultivated plants display a large number of modified characteristics. As a rule, the plants are sturdier, their

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fruits larger and more abundant. The taste, nutritive value and storability of the fruits are far more superior. The cultivation conditions and yields are far more favourable."

New developments in plant breeding

How did all these progressive developments come to pass?

Let's stick to plant breeding. The main objective here is the development of new varieties in which as many valuable qualities as possible are concentrated. The most reliable method is cross-breeding and subsequent selection of suitable progeny. In principle, this form of breeding is carried out according to the rule drawn up 125 years ago by Gregor Johann Mendel, an Austrian Augustinian abbot.

The Max Planck Institute of Breeding Research, Cologne, describes the "Conventional Breeding Method taking Grain as an Example":

"In the case of corn, breeding today continues to be largely based on conventional methods, in other words, cross-breeding and subsequent selection because it is still extremely difficult to apply modern plant breeding to the various species of corn. The economically important species - wheat and barley - are self-fertilizing. As a result of their continuous, natural inbreeding, these plants achieve a high degree of homozygosis within the space of several generations. They are distinguished by their large measure of uniformity and constancy over the years. If a single, largely homozygous plant multiplies, a new 'variety' is the result ...

This development of new varieties from one "line", however, also has certain disadvantages. Genetic unifor-

ity can make the plant stands of these species vulnerable to any form of stress (weather factors, epidemics). Ways are now being sought of making a genetic variety possible without the seed market getting out of control.

Initially, simulation experiments were carried out with variety mixtures. Several hundred plots, five square metres in area, were sown in each case with mixtures of two to six varieties of spring barley, winter barley or winter wheat. The results showed that considerable advantages really are obtainable with genetically varied corn stands. They are less afflicted by fungal diseases and consequently provide higher yields. With only marginal use of plant protection agents, variety mixtures can be just as productive as chemically protected crops. In other words, the cultivation of mixed varieties in agiculture would presumably not only result in increased yields; it would also lead to the reduced employment of plant protection agents."

The Institute goes on to say:

"Interest is also being concentrated on finding out what mutations should be undertaken to breed even better varieties. Preliminary investigations show that the successes achieved in corn breeding in the last hundred years stem solely from the fact that the hereditary traits for the development of the grains in an ear of corn were changed. Modern varieties boast of 60 percent more grains per ear than those of the 19th century. Hand in hand with augmented fertility of the individual ears, the stalk was shortened (to be able to bear the weight of the heavy ear) and the dry matter released thereby stored in the more numerous grains ..."

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One of the eventual research objectives is the tapping of new genetic sources offering various characteristics. Of special interest are genes which enhance vegetable powers of resistance to disease and stress, and those which improve the quality of the products. These genes can occur in related wild forms or primitive varieties and, by cross-breeding, be transferred to cultivated strains. The Institute, for instance, has succeeded in transferring the resistive powers of couch grass to wheat. Further crosses of this type are aimed at achieving improved resistance to fungal diseases in the various corn species and improvement in the baking quality of wheat.

Ever since biologists discovered that DNA (deoxyribonucleic acid) was the carrier of hereditary information contained in the nucleus of all vegetable, animal and human organisms, efforts have been made to decipher the code. The aim is to decipher all genes as different hereditary factors - in other words, as sections of the DNA containing the code for the individual components of the organism.

In the case of genetic engineering in plant breeding and agriculture, the main objective, therefore, is the transfer of an interesting gene into an interesting cultivar by means of the in vitro technique, i.e. test tube. Professor Saedler explains:

> "The first and most important possibility lies in the time saved in the production of new strains; second, it will be possible to develop gene combinations which are inconceivable by natural sexual processes; third, once the first two goals have been achieved, they will result in a considerable reduction in the use of agrochemicals in the farming industry - a goal which many are also pursuing without resort to genetic engineering."

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Examples of genetically engineered mutations in plants

The following example of a genetically engineered mutation illustrates what lies within the realms of possibility:

Up to now, the petunia has only existed in white, blue and red. The molecular geneticists at the Cologne-based Max Planck Institute, however, have taken it upon themselves to breed a salmon-pink variety of this flower - so beloved of all German balcony gardeners. In 1990, they are planning to cultivate 4o,ooo genetically engineered petunia plants in a field belonging to the Institute.

Basically, experiments with genetically manipulated plants are forbidden in open beds in the Federal Republic of Germany. Even so, the responsible authority - the Central Commission for Biological Safety - has granted the Cologne scientists' application for exemption.

The new colour to be bestowed on this flower, however, is nothing more than an eyecatching embellishment. In reality, the experiment is designed to show how the breeding process can be shortened - within the framework of pure, basic research; furthermore, the experiment with these plants is to reveal the laws governing the change in hereditary information in plants in a natural manner; in this open-bed experiment, so-called "jumping genes" could result in a series of mutations which will once more change the salmon-pink blossoms into another colour.

A further example: the potato. It is not unusual for this plant to be infested by the leaf-roll virus. The latter only attacks the cultivated potato, and not the woody nightshade "bittersweet" - a wild plant of a related species. The object of research in this case is to denaturate the potato for the virus and to whet its appetite for bittersweet, instead.

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In this context, Professor Hans Ross, from the Max Planck Institute, states: "In the case of bittersweet, it is imperative to find out which gene puts the plant pest off and to feed this tiny piece of hereditary information into the potato's DNA chain."

Since the basic elements of hereditary information are identical in plants, animals and humans, characteristics with special effects from all forms of life can be systematically built into cultivated plants.

There is a large number of other possible uses open to genetic engineering:

- with its help, new foodstuffs and animal fodder, as well as complicated, chemical substances can be manufactured;

- quality and assured yield in vegetable and animal production can be enhanced, for example, by improving powers of resistance, developing new, energy-saving and non-pollutive production processes. Example: plants which grow in the desert and which need less fertilizer and plant protection agents.

Last but not least, productive plant varieties can help to improve the supply of food in developing countries without making increased operational efforts necessary. Research is primarily trying to rebreed location-related, traditional cultures which are adjusted to climatic conditions. In Latin America, for instance, where potatoes were grown for thousands of years, original cultures are to be more widely spread once more. Even the Incas were able to grow frost-resistant species up to a height of 4,000 metres in the Andes.

Federal Research Minister Heinz Riesenhuber recently outlined the biotechnological possibilities in the farming industry:

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"Opportunities for plant breeding and plant protection emerge from investigations into the mechanisms which enable plants to resist attack by fungal diseases. This also includes the development of biotechnical methods of plant breeding - such as cellular fusion, genetic transfer and cell or tissue culture techniques in order to reduce breeding periods which as yet are between ten and twenty years to maybe six to ten years. Even today, it is possible to transfer genes beyond the limits of their species. By this means, plants are endowed with characteristics they do not normally possess for the qualitatively superior production of substances which are in great demand (such as highly-quality proteins, carbohydrates, oils and fats which are in particular demand because of their characteristics). In this way, it will prove possible to provide the world's growing population with sufficient food and industry with renewable raw materials."

Biotechnology in animal production

Health, breeding and fodder are the three main areas within which biotechnology can be applied in animal production. As is the case in human medicine, biotechnology, especially genetic engineering, offers a broad range of possible application in veterinary medicine. With the help of diagostic agents, created by genetic engineering, diseases, manner and spread of pathogens can be established more accurately and at an earlier point in time - such as in the case of latent viral infections - than is possible using conventional methods. The basic requirements to this end are the possibility of breeding specific animal cells, enhancing the multiplication of viruses in cell cultures and identifying and analyzing viral and microbial genes.

Therapeutic treatment and prevention of animal diseases can be further improved by the use of genetically engineered products: these include regulators for the immunological system, antibodies and new vaccines on the basis of genetically engin-

eered viral components or variations.

In the case of animal production, biotechnological processes can be used first and foremost in the areas of fertility, adaptability, management characteristics, performance stability, useful life and product quality. Possibilities of further acceleration of breeding progress or of lowering costs are offered by processes such as in vitro insemination of ova, or the long-term storage, division and transfer of embryos.

The possible application of biotechnology in animal fodder includes the production of metabolically active substances, which help enhance productivity in animal improvement, in the manufacture of new feedstuffs (unicellular protein), the microbial disintegration of residual and waste substances for feeding purposes or improvement of the nutritive value, especially feedstuffs which are rich in crude fibres, and in better preservation processes. In addition, rapid enzymatic and microbial methods can be developed to improve the evalution of feedstuffs (nutrient availability, energy and damaging-substance content). As fodder costs account for up to 60 percent of the total outlay, great opportunities of lowering stock-keeping costs are offered here. What is more, microbial and enzymatic methods of examining feedstuffs can contribute to a reduction in animal experiments.

Biotechnology and foodstuffs

Products such as vinegar, beer, wine, sour dough, cheese and yoghurt have been known since the early days of human civilization: man has always endeavoured to preserve foodstuffs. Lactive acid bacteria in foodstuffs, for instance, prevent the growth of putrefactive and pathogenic germs which allow animal and vegetable protein, such as in cheese or sour vegetables, to be exceptionally well preserved biologically - even in hot countries. Apart from bacteria and yeast, mould is also a highly desired micro-organism in food manufacture;

mould preserves the products and improves the aroma and appearance of cheese, raw sausage and uncooked ham.

The future of biotechnology in this sector lies in the genetic improvement of the bacteria and fungi used, and the biotechnological production of enzymes and natural aromatic and gustatory substances. Improved methods of preservation can help reduce the danger of microbial poisoning and the use of additives. In such circumstances, what is more, problematic residues are avoided and energy saved.

3. State and prospects of biological research and development in the Federal Republic of Germany

A report published by the Federal Minister of Research and Technology in 1989 (entitled "Programmreport Biotechnologie") confirms that German research has regained its leading position in the outstanding fields of modern, biological research, including biotechnology and genetic engineering - as well as allied areas such as plant breeding.

The funds provided by the Minister have contributed in no small way to the promotion of research and development: within the space of five years, expenditure almost doubled from DM 123 million in 1984 to DM 259 million in 1988.

Main research centres

Seven central research centres in biotechnology and genetic engineering are funded by Bonn. They are the genetic centres in Berlin(West), Heidelberg, Cologne and Munich, the Centre for Molecular Biology in Hamburg and the central focal-point research projects in bioprocess technology (Brunswick, Göttingen, Hanover) and bioprocess technique (Stuttgart).

The promotive measures were also taken up by 220 private enterprises, 76 percent of whom are of medium-size. The exten-

sion of the model project "The Establishment of Technology-oriented Enterprises" resulted in the setting up of 34 new firms.

"Great attention was paid to the brisk development of basic research for biological and biotechnical research which refers to the necessary preliminary research for industrial product development and state prophylactic research for the improvement of conditions of existence (health, environment)," the report states. "Supplementary to the strengthening of biological basic research, the promotion of market-oriented developments was extended and supplemented by indirect measures to enable medium-size enterprises to pick up problem solutions."

In other words, promotion machinery extends from direct funding of basic research and industrial, integrated research (with flexible transfers - adjusted to requirements in each case - to indirect, promotive measures for the development stage in industry and the broad translation into industrial practice) to the setting up of enterprises mentioned above.

International cooperation

The research scene is also being considerably boosted by the institutional promotion of biotechnology in a large research centre - the Society for Biotechnological Research/GBF - in Brunswick. Apart from its main commitments, the GBF has developed an International Training and Cooperation Programme (ITB) for scientists from countries in Africa, Asia and Latin America with the long-term objective of establishing bilateral institutes and firms on these continents and, within the framework of these relations, realizing projects in the field of industrial biotechnology. The GBF, incidentally, provides a detailed overview of its research activities in a scientific, progress report which is published annually.

An example taken from the area "Subject-related Integrated Research and Project Promotion" illustrates the agricultural

relevance of biological research. The report by the Federal Ministry of Research and Technology (BMFT) states:

"A research institute for animal hygiene in the tropics and a young investment firm in the field of bioprocess technology took it upon themselves to develop an efficient, easy-to-use - and thus ideal for developing countries - bioreactor system for the production of antiviral vaccines against tropical animal diseases. The initial applications in the Sudan and Latin America are indicative of promising results for this process. Animal cell lines with high virus multiplication were used and after a cascade of viral infection and processing were identified as the suitable lines. The cooperation partners view their development lines as so flexible, reliable and economical that vaccines can be made available in large quantities to combat the devastating and socio-economically serious animal diseases in the subtropics and tropics."

Biotechnology has become a working area for international cooperation, the heart of which is represented by cooperation within the European Community (EC). Apart from research collaboration with other industrialized countries, there are now concrete, cooperative projects in the field of biotechnology with countries in the Third World - such as Indonesia, Brazil, Argentina, China and India, for example.

Statutory regulations on "biological safety" will simplify the conditions of approval for manufacturing firms. Unclarified conditions were the reason why a number of leading German enterprises chose to transfer their production capacities to other countries, mainly the USA. Now the Federal Republic of Germany can be more attractive as a location once more.

4. The risks and dangers involved in genetic engineering

We all remember the year 1982 when American scientists created a giant mouse: they had transplanted the rat-gene contain-

ing the information for the growth hormone into a mouse. Not long afterwards, human growth-genes were implanted in pigs: the result was they really did put on more flesh - but also became more susceptible to illnesses.

This mixing of the species prompted critics to raise their voices. At its synod in 1988, the German Protestant Church passed the following resolution: "Man has no right to experiment with new combinations of species through the abuse of genetic possibilities."

The advantages mentioned above contrast sharply with the negative aspects of genetic engineering which must be prevented at all costs. But even in agriculture, the use of genetic technology should not prompt hopes to fly too high.

Federal Chancellor Helmut Kohl gave a graphic formulation: "The ideal of a perfect world outreaches human possibilities and human measure: anyone desirous of heaven on earth, will turn life into hell." On the other hand, he said, "it is not only permissible - in line with the Christian image - but indeed imperative to improve the life of man through scientific research and the application of its findings."

Federal Agricultural Minister Ignaz Kiechle has also spoken out against basic rejection of biotechnology and genetic engineering on the grounds that it is the "work of the devil" or an "inadmissible game with genes". On the contrary, it is the Federal Government's goal to develop the justified opportunities offered by genetic engineering to the exclusion of unacceptable risks for human beings, animals and the environment.

The Genetic Engineering Act

In other words, the draft law regulating genetic engineering of 12 July 1989 (Gentechnik-Gesetz), to be enacted on 1 January 1991, has a double function: it is to provide the legal

basis for further exploration, development and use of genetic engineering and, at the same time, protect human beings and the environment from possible dangers and prevent risks.

These statutory regulations were necessary, the Chancellor stressed, "to ensure that there are no loopholes for the over-ambitious". This was endorsed by Foreign Minister Hans-Dietrich Genscher: "We must build a fire wall against the abuse of genetic engineering."

This "basic legislation" in regard to genetic engineering, which has now been resolved, is designed, inter alia, to regularize graduated safety measures and approval requirements for the differentiated risk level of individual projects as well as the responsibility of the central, technical body at federal level for complex safety matters, thus contributing to the essential uniformity and acceleration of approval procedure.

This law is to cater for the principle of prevention. "We must not bide our time until the damage has occurred or the law is violated: we must take the necessary steps beforehand," Federal Chancellor Helmut Kohl said. "We must do all we can to prevent the occurrence of abuses or possibly irreparable maldevelopments." Furthermore, it is a matter of preserving society's consensus on medical or technological progress. After all, people have a right to be informed or have a say about new developments which concern the lives of all, particularly about such serious questions as the opportunities and dangers of genetic technology. "Here, scientists from all fields are called upon to contribute their expertise and work together with citizens and politicians to create a future worthy of human beings," Helmut Kohl emphasized.

Federal Minister of Justice Hans Engelhard is also geared to "the broad consensus of social forces" when it is a matter of patenting and variety protection of genetically engineered

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manipulations. In this context, he is of the opinion that industrial sectors specializing in genetic engineering will enjoy a considerably and disproportionally increasing share of industrial production in future.

"Only if one pauses to reflect that the estimated turnover of biotechnological and genetically engineered products could be as much as DM 500 billion annually by the year 2000," Engelhard stated recently, "does it become apparent that the possibility of acquiring industrial property rights is of tremendous importance economically for enterprises engaged in research and production."

Even now, patent protection is possible in the Federal Republic of Germany for:

- microbiological processes and process products (e.g. microorganisms),
- the invention of "new" plants, provided they do not represent varieties,
- technical processes for breeding plants, plant species, animals and animal breeds, and
- special research findings, such as genes, enzymes, plasmids.

This makes innovation an attractive proposition; there are also no disadvantages of location for German enterprises in patent law.

But here, too, we hear a critical voice: "Hunger in the world is often quoted as the need for genetic engineering," commented Ernst U. von Weizsäcker, director of the Institute of European Environment Policy and chairman of the board of the Association of German Scientists, in a lecture on 'Biotechnology and genetic engineering - progress with no limits?'. "On closer examination this argument does not hold water. If we are not careful, an increase in genetic-technical productivity will not benefit the hungry but those whose 'need' is also expressed in purchasing power."

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Even so, genetic engineering could still help improve the adaptation of food plants to unfavourable locations, expand arable land globally and increase the productivity of cultivated plants. In this way it may even become possible one day to practise arable farming in arid regions of Africa, Asia and Latin America.

5. Regrowing materials - a future prospect?

The use of plants as raw materials for industry is not new. Traditional, agricultural products - such as wheat, potatoes or maize - have long been indispensable sources of starch for adhesives and paper manufacture. Vegetable raw materials have always been required for the production of spices and medicaments. Until the discovery of synthetic fibres, farms were solely responsible for supplying the textile industry with fibres. Leather and wool from animals continue to be irreplaceable and renewable raw materials.

Basically speaking, all agricultural and forestry products are regrowing or renewable raw materials. In contrast to fossil raw materials, such as mineral oil or coal, however, which are rapidly becoming more and more scarce, natural, regrowing products represent an endless source of raw materials.

The term "regrowing" or "renewable raw materials" was coined in the early 1970s when the general public was made aware of the limited character of mineral and fossil resources through the oil crisis. Discussion on the safeguarding of raw material supplies principally concerned the mineral oil and chemical industries. Thanks to biological-technical progress in agriculture, farmers were producing foodstuffs surplus to self-sufficiency - foodstuffs which could no longer be sold on the world market. Thoughts were now given to the cultivation of regrowing raw materials for industrial purposes. This would help counter, at least partially, overproduction in agriculture, provide farmers with alternative sources of income and promote non-pollutive cultivation methods.

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Politico-agrarian discussion on regrowing raw materials

In summer 1989, Agricultural Minister Ignaz Kiechle presented a report on renewable raw materials which had been prepared jointly with the eleven Bundesländer (constituent states): "Today, agricultural raw materials for industrial purposes are available at world-market prices and are being made use of in increasing measure. European agriculture, however, is still unable to produce on a cost-covering basis at world-market prices. As far as renewable raw materials - and foodstuffs - are concerned, a bridge must be built between manufacture and marketing. One possibility is the promotion of research. To this end, the Federal Government made DM 300 million available between 1980 and 1988. It is currently spending almost DM 50 million annually. We are thus doing far more than other EC countries. I consider it essential to continue this precautionary policy."

According to Kiechle's ideas, these sums of money should be spent, for example, on largish pilot and demonstration projects in the fields of sugar, starch, oils and fats, fibrous materials, wood and energy. The Federal Republic of Germany supports the view that the other countries in the European Community (EC) should likewise decide on increased activities in this sector; after all, overproduction is consuming a lot of money on the European agricultural commodities markets. EC-wide, it is reckoned that, by the year 2000, some 10 to 15 million hectares of farmland can be cultivated with regrowing raw materials. According to calculations by the Federal Institute of Agriculture, two to three million hectares will be available for the production of basic plant materials for industrial purposes in the Federal Republic of Germany around the turn of the century.

6. Industrial use of regrowing raw materials

We can no longer imagine daily life without synthetic materials from mineral oil. Low prices for coal, mineral oil and natural gas are currently not competing with vegetable or an-

imal raw materials, and, after all, mineral oil products have shown themselves to be very durable and of universal application. Even so, natural basic materials will be competing more and more with petrochemical raw materials in future simply because progress in biotechnology and process engineering favour their industrial usage long-term. Neither must we forget health-minded consumers who are demanding natural products in increasing measure - such as in the case of cosmetics, paints and textiles.

The use of renewable raw materials helps take the pressure off the limited fossil resources; at the same time, it makes industry more immune to crises and price fluctuations on the international raw material markets. In many cases, non-pollutive, industrial products can be made from vegetable and animal basic materials since these products, which consist of biologically structured substances, can, under given conditions, be completely decomposed by biological means once more. Potential customers for regrowing raw materials are, first and foremost, the chemical industry, which, even today, obtains about 10 percent of its raw materials from natural, basic vegetable sources, the fuel, cellulose and paper industries.

Oils and fats - non-pollutive, natural products are conquering the market

Since ancient times, expensive vegetable oils, and animal fats such as lanolin (taken from the wool fat in sheep's wool) have been used for beauty culture. In many buildings, one can still see old floors covered with linoleum, one third of which consists of linseed oil and which is being laid on floors once more in increasing measure. Linseed oil is being used more and more as a varnish and for the manufacture of non-pollutive, natural paints. Detergents from beef tallow, lubricants from rape seed, lacquers from soya bean oil - the list of products made from oils and fats is surprisingly long.

At the present time, the European chemical industry is importing three-quarters of its vegetable oils and fats, mainly from oil and coconut plantations in Africa and Asia. Some 300,000 tonnes of vegetable oils and fats, produced in Europe, comprise the fundamental basis for the manufacture of washing powders and detergents, cosmetics, synthetics, rubber, paints, lacquers and lubricants. Because of their composition of fatty acids and a certain number of carbon atoms, known as medium-chain fatty acids, oils and fats from palm trees are of great value to the chemical industry. Industry also makes limited use of oils and fats with long-chain fatty acids which can be produced under Central European growing conditions. Biotechnology will play a more important part in this field in future and is striving to supply industry with made-to-measure raw materials.

Yellow-flowering rape is the most productive oil plant and the one best adapted to German cultivating conditions: specifically for the food industry, one particular substance - erucic acid - was bred out of the plant. This acid, however, is indispensable in technical-industrial usage, such as in the manufacture of synthetics, lacquers and emulsifying agents. Consequently, plant breeders in the Federal Republic of Germany are intent on developing an "industrial rape" with as high a content of erucic acid as possible, in addition to the "foodstuff rape".

Rape oil has been used for some years now in forestry. In combination with natural additives it is used as a lubricant for chain saws. In this way, forest soil is not so encumbered with mineral substances which are difficult to reduce since rape oil, like other products with a vegetable-oil base, can be completely degraded to the fundamental components of carbon dioxide and water with the use of micro-organisms. Diverse products, which are kind to both the environment and resources, have been developed for other areas of usage - such as hydraulic oil for agricultural and forestry machinery or as anti-corrosive agents.

There is one particular fatty acid, oleic acid, which industry would use in large quantities if it had the desired purity and, above all, if it were available at competitive prices. Two varieties possess oils which consist of up to 80 to 90 percent oleic acid: a variant of the sunflower and the cruciferous-leafed spurge. Here, too, plant breeders are trying to adapt these species to the growing and climatic conditions in Germany. Currently, industrial enterprises in the EC require some 2.7 million tonnes of fats and oils. A growing consumption (about 0.3 to 0.5 million tonnes EC-wide) of vegetable oils and fats is anticipated in the next decade. One hectare planted with rape or sunflowers, for instance, can produce some 1,200 kilogrammes of oil.

Starch - highly promising prospects

About 500 end products - including such well-known ones as paper, corrugated cardboard, washing starch and toothpaste - contain starch from maize, potatoes or wheat. In the chemical and paper industries, starch is used for the manufacture of adhesives, paper products, binding agents, as a process material for the production of synthetics or pharmaceutical goods and has already become an indispensable raw material.

Progress in biotechnology has meantime opened up new markets for starch. German politicians see opportunities of growth, particularly in the manufacture of synthetics: starch, for instance, can be built into synthetics as filling material, such as in the case of polyurethane foam. The proportion of starch is biologically degradable and reduces the amount of synthetic material required. Synthetics can also be made from glucose, a cleavage product of starch - whereby the glucose acts as a nutrient medium for bacteria. These, in turn, manufacture other industrially useful substances.

Of late, plant breeding has been working on the pea to be able to offer industry an additional starch raw material. The marrowfat pea stores starch of a special quality, its seeds con-

tain much amylose, a hydrosoluble form of starch which is exceptionally well suited to the manufacture of completely biologically degradable foil.

About 1.9 million tonnes of starch are used for industrial purposes in the EC annually, 385,000 tonnes of which are accounted for by the Federal Republic of Germany. As far as the product line starch is concerned, the Federal Agricultural Ministry is optimistic and is anticipating the largest consumption increase in the still relatively insignificant areas of chemicals, pharmaceutics and synthetics. The experts are also pinning high hopes on biotechnological progress which is to enable the breeding of particularly high-yield starch plants with large quantities of amylose.

Sugar - valuable substances for the chemical industry

Because of its high degree of purity, sugar is ideal for the chemical industry; it can be used unchanged as a fermentative, raw material and as a chemical component in industry. During the fermentation process, for which the greater part of industrial sugar is used, bacteria and fungi use sugar as a source of food and, in so doing, produce valuable substances, especially organic acids such as citric acid and amino acids, in other words, protein components, or antibiotics such as penicillin, and vitamins.

Sugar beet is still Europe's sugar supplier Number One. In the meantime, plant breeders have been working on the introduction of a new, sugar-supplying plant - sugar millet - to produce the vegetable raw material less expensively than at present and to loosen up the crop rotation in the intensively used soils. The concentrated cultivation of sugar beet can lead to crop rotation diseases which reduce farmers' yields and which cannot be adequately controlled chemically. Sugar millet, which is related to sugar cane, stores the sugar in the stem and leaf tissue. There are still technical difficulties, however, in preserving the sugar juice pressed out.

Further alternative suppliers of sugar are the little known cultivated species topinambur (a cultivated sunflower, hard with an edible tuber), and chicory (a plant from the composite family with fleshy roots). Its storage substance, inulin, provides a high-grade fructose syrup (fruit-sugar juice) whose sweetening properties are one-and-a-half to two times greater than refined sugar.

EC sugar production for the summer of 1988 is put at a total of 14 million tonnes. 2.7 million tonnes were produced by the Federal Republic of Germany. Of this figure, 175,000 tonnes were used for the chemical-technical area in 1987/88, 56,000 tonnes more than the previous year. In 1987/88 the chemical industry in the Federal Republic of Germany consumed 33,000 tonnes (previous year: 19,100 tonnes).

But there is still a lack of simple and economically viable processes for the use of sugar as a non-pollutive, raw material in the production of synthetics. For processes such as this, further research must be undertaken.

Plant fibres and the outstanding example of flax

With the exception of cotton, the triumphal march of chemical fibres put natural fibres - such as hemp and flax - into the shade for many years. The last flax processing plant was closed in 1959; the growing of hemp is forbidden by the Narcotics Law (the drug marihuana can be made from hemp) and only a few thousand hectares are still being cultivated in the EC - for paper production. Even so, flax has been experiencing a renaissance for some little time now.

"Linen creases nobly", German and Italian couturiers claimed several years ago: since then, casual linen clothes have been celebrating undreamed-of triumphs. Linen is the end product of the age-old, cultivated plant flax from whose fibres the

(once more) popular material is manufactured.

Cotton and the mechanical looms, on which linen fibres could not be processed very well, forced back the cultivation of flax. The cultivation of flax was completely discontinued in the Federal Republic of Germany. This was also due, in part, to the pressure of competition by synthetic fibres. But for the last three years or so odd fields of flax, with their blue or white flowers, have been reappearing. A market for indigenous fibres is gradually beginning to develop from the initial pilot projects by the German Federal Government and the Bundesländer (abour 850 hectares cultivated in 1987). By 1989 the cultivation of flax had grown to 2,200 hectares. Three processing plants - known as swingles - have already been built: a further three are planned or completed - federal-wide.

Flax is well adapted to Central European climatic conditions and can literally be produced in any of the arable farming areas in the Federal Republic of Germany. On many farms it can help extend the often too limited crop rotations. It requires very little fertilizing or plant protection agents. Basically, almost the whole plant can be processed. It is here that it becomes apparent how many possibilities of usage flax offers. The long fibres are a high-grade raw material for the textile industry; the short fibres, which occur in the traditional processing technique, can be used for industrial purposes, such as for insulating materials, substitute materials for asbestos, wallpaper, furniture filling or paper manufacture. Linseeds, the fruit, in other words, are processed mainly into technical oil by oil mills: they are also used in the chemical, cosmetics and food industries - as well as for the manufacture of linoleum covering. The flax wax, which is to be found on the plant's surface and in the fibre stricks, is used by the cosmetics and pharmaceutical industries. Last but not least, the shives - the wooden components of the flax's stem - can be used for the production of energy, or the manufacture of paper or particle boards.

One hectare of cultivated area produces about 9,500 kilos of flax straw and seed; this yields, on average, 826 kilos of long fibres, 445 kilos of short fibres, 4,200 kilos of shives, 1,000 kilos of linseed and 60 kilos of wax. According to current estimates, linen's share of textile-fibre consumption as a whole will increase from 1 to 2 or 3 percent in the coming years - a market potential of 90,000 tonnes for the Federal Republic of Germany. At the present time, German industry needs the yield of about 6,000 hectares. Including imported tissues and yarns, the consumption is put at a total of some 25,000 tonnes of linen yarn.

The Federal Agricultural Ministry is not only anticipating increased requirements in pure linen articles but also a large market in linen mixed tissues - which can, for the most part, be manufactured on cotton textile machines. It is important that the linen made in the Federal Republic of Germany be of a high quality.

Wood - the prospects for cellulose

Wood is the regrowing raw material par excellence - a unique product of nature and endowed with many advantages.

Some three-and-a-half billion hectares of the world's surface are covered in forest; half of it is in tropical regions. These forests provide 3.4 billion cubic metres of wood yearly. In the EC some 115 million m^3 of wood are felled annually, in the Federal Republic of Germany 30 million m^3. In recent years, the Federal Republic imported 60 million m^3 of raw wood equivalents in wood and wood products. On the other hand, the Federal Republic of Germany exported raw wood and wooden products in the region of 40 million m^3. The Federal Republic is the third-largest consumer of paper products in the world and the fifth-largest exporter of high-grade paper products.

Wood is used primarily in its solid state, for veneers or work material in the building and furniture industries. A further area is the wood pulp industry, particularly the production of paper and cardboard. High-grade pulps of almost pure cellulose are basic products for the manufacture of various chemical goods. A good 9.5 million tonnes of paper and cardboard are produced in the Federal Republic of Germany annually. The experts reckon this figure will have risen to 12.3 million tonnes by the year 2000.

The chemical pulp and paper sector is regarded as the industrial area with the most promising prospects. This sector has a considerable market potential which the domestic pulp industry has been unable to exploit adequately. The reasons for this stem from the fact that, compared with other countries, the stricter environment regulations and questions of safeguarding raw material supplies have hitherto prevented the introduction of the qualitatively better sulphate process for the manufacture of cellulose as the only alternative to the sulphide process. Whether or not the growth in the cellulose and paper sector will benefit the forest economy will largely depend on the successful implementation of new wood-pulping processes. The Federal Republic of Germany still has to import 80 percent of its cellulose requirements (it currently consumes over 3.6 million tonnes yearly); new processes on the basis of the organosolve principle (use of organic solvents) promise prospects of success. The Federal Research Institute of Forest and Wood Economy, Hamburg, has developed a process free from harmful substances known as "Acetosolv" (the use of acetic acid and hydrochloric acid, leaving no chemical residue), and which provides a high-grade, bleached cellulose. Apart from the cellulose, valuable, organic raw materials from wood - lignine and hemicellulose - remain intact and can be used by the chemical industry. From these are manufactured such chemical substances as funfural, polyester, nylon, perlon etc, and phenol, the basis of adhesives, resins etc. A corresponding pilot plant started operations in

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Bundesland Baden-Württemberg in February 1989.

If efforts to develop these new processes technologically - they showed great promise at laboratory level - turn out to be successful and result in a substantial increase in cellulose and paper production in the Federal Republic of Germany, increased wood production on agricultural land will offer rosy future prospects for German agriculture and forestry.

As a regrowing raw material, wood calls for great patience. If farmland is to be afforested, the yield in the case of conifers would be after 25 to 30 years; in the case of deciduous plantations, 40 to 45 years. An alternative is offered by fast-growing tree species with a cutting cycle of two to twenty years. This form of cultivation - "short rotation" - is mainly concerned with willow, poplar and alder woods and is currently at the development stage.

7. Regrowing raw materials as energy sources

All species of plants, which store carbohydrates or oil in the main, are suitable for the production of liquid energy carriers. Sugar, starch and inulin can be fermented into alcohol. The parts of plants which contain lignocellulose provide energy directly through combustion or indirectly through liquefaction. Under given conditions, vegetable oils can be used as fuels for diesel engines.

Compared with the total energy supply with electric current, heat and fuels, the share enjoyed by bioenergy will be relatively limited in all probability in industrialized countries. Even so, a small, but not insignificant share of total requirements may well be covered by bioenergy in the fuel sector at some future date.

One important, environmental aspect in the production of energy from biomass is the fact that regrowing raw materials are in-

tegrated into the natural carbon-dioxide cycle. Any carbon dioxide occurring during their conversion to energy was previously withdrawn from the atmosphere during the development of the biomass.

Alcohol becomes "fit for transport"

For some years now, using potatoes, maize and beet as the basis for motor fuels has presented no problem technically. In fact, there are three pilot plants for the large scale production of bioethanol in the Federal Republic of Germany. Pure alcohol is obtained by fermenting substrates rich in carbohydrates (sugar or starch) with the help of yeasts, or bacteria and distillation. About one million hectolitres of agricultural alcohol is produced in the Federal Republic of Germany annually; some 15 percent is used for technical purposes and the remainder for foodstuffs and semi-luxury foods. The production of ethanol could well acquire great importance for the motor and other fuels sector. The technical problems have been solved for the most part - but there are still risks, principally of an economic nature.

If ethanol is mixed with fuels for spark-ignition engines, the proportion of carbon monoxide and unburnt hydrocarbons in the exhaust gas is reduced. In the case of nitrogen oxides, however, no reduction has been registered. A large amount of residue occurs in the conversion of agricultural products to ethanol, however. Traditionally, these remains are processed into animal feed or sprayed over the planting area. Just as the animal feed market has limited absorption capacity, the sprinkling process harbours ecological risks. In other words, special facilities must be considered which utilize the byproducts and dispose of the waste. A pilot plant of this nature in Ahausen-Eversen (Lower Saxony), however, has shown that the harmless disposal of waste products adds greatly to the actual production costs.

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A five-percent admixture of ethanol in spark-ignition engine fuels would mean an additional requirement annually of over one million tonnes, and almost five million in the EC as a whole. Production from potatoes, sugar and fodder beet would make a crop acreage of 300,000 to 400,000 hectares necessary.

Vegetable oils as fuels and lubricants

The use of vegetable oil as motor fuel is by no means a novelty any more. Cleansed plant oil can be used with certain diesel engines; it is not without problems at low temperatures, however. Chemically modified (esterified) vegetable oil is considerably less problematical but the additional manufacturing process creates substantial, additional costs.

A duo-therm engine called "Elsbett-Motor" is to be built into mass-produced tractors in the near future. This development had made front-page news: it has been designed by Ludwig Elsbett, a German engineer. The direct-injection engine is fitted with largely self-cleansing pintle-type nozzles and there is limited play between pistons and cylinder. This makes it difficult for possible combustion residue to surge forward. A more refined fuel processing by means of special pump-jet elements and a special air flow, which creates a hot centre of combustion in a cold mantle in the cylinder, makes this invention well-suited to vegetable oil.

In principle, all vegetable oils can be used as motor fuel. In the Federal Republic of Germany, winter rape is the oil plant with the highest yield; production costs are very high, however. Its economic efficiency, as in the case of bioethanol, depends on the price level of fossil raw materials.

"In regard to the use of vegetable oil as a motor fuel," a survey by the Federal Agricultural Ministry states, "clearly positive, ecological aspects have been established in an initial comparison with diesel-engine fuels - such as the fact that in the case of gaseous, noxious matter discharge, the

soot level is lower. Furthermore, rape-oil motor fuel, unlike diesel, can be classified as being of extremely low sulphur-content. What is more, rape oil is relatively safe to store and transport: its danger level is unclassified and, in the case of seepage, decomposes rapidly. The last-mentioned advantage is already being exploited in the production of lubricants for chains on motor saws."

The lubricants market may well turn out to be a large and promising outlet for rape-oil; after all, something like a million tonnes of lubricants are consumed in the Federal Republic of Germany yearly. The German forest economy, for example, uses 6,000 tonnes of chain lubricants for saws annually. A large part of the oil gets lost during operations and pollutes the evironment. The manufacturers of lubricants for saw chains have acknoweledged rape-oil as a non-pollutive alternative. About 55 products, which have been declared non-pollutant, are now being marketed.

Meantime, hydraulic oil on a rape-oil basis is likewise to be had in Europe. Further areas of application are fuelling hopes of many thousand tonnes of rape-oil being marketed for lubricating purposes in the next few years. The byproducts of the oil production can, depending on their quality in each case, be used as animal fodder or fertilizing agents; whatever the case may be, the environment is in no way polluted.

Heat and electricity from biomass - possibilities for developing countries

Straw, which accrues in great quantities in farming, residual wood and bark, are agricultural and forestry waste which provides energy. True, their thermal value is inferior to that of fossil energy carriers; firewood, for instance, has only one-third of the calorific value of mineral oil. It is therefore purposive and economical to make use of large quantities of biomass where it normally occurs - such as burning bales

of straw as a fuel in farming operations.

There are experiments underway which are aimed at the systematic cultivation of energy plants - the most suitable of which seem to be annuals, such as corn or rape, or perennial plants such as elephant or reed grass, as well as fast-growing species of trees.

Last but not least, biogas can be manufactured from regrowing raw materials. Some 120 biogas plants have been erected in the Federal Republic of Germany since 1973. When vegetable and animal remains rot in airtight conditions, a gas is created with a methane content of over 50 percent and a high thermal value. The advantage here is the fact that the waste matter is being simultaneously disposed of. At present, this form of energy production costs twice as much as heating oil.

Be that as it may, biogas plants are increasing in importance in developing countries since they represent an alternative to the ever dwindling raw material firewood. Two billion persons, living for the most part in developing countries, are dependent on wood as fuel. Not least because of land clearance by fire (to obtain arable and pasture land), 11 million hectares of woodland are lost annually; only 1 million hectares are re-afforested yearly, however. Within the framework of its "Special Energy Programme", the German Society for Technical Cooperation (GTZ) is promoting, in particular, the construction of biogas plants in the Third World. Such plants are well worth while, especially in regions with intensive stock breeding.

In Mali, West Africa, a rice mill was equipped with a biogas power station which manufactures its own energy from the vegetable residue. By means of a gasification process, lean gas for one kilowatt hour of current can be produced from just under two-and-a-half kilos of rice husks. The rice mill in Mali produces an average of 1,600,000 kilowatt hours annually - of which only 600,000 kilowatt hours are required. In this

way, electricity can be supplied to other consumers in surrounding villages. Thanks to this plant, some 350,000 litres of diesel fuel can be saved yearly.

8. The future development of regrowing raw materials

As this paper has shown, renewable raw material sources are already an integral part of raw material supplies; they will also continue to enjoy a firm place in the industrial and technical sectors in future.

Although fossil raw materials are becoming scarcer and more expensive, it is reckoned that their price increases will remain relatively marginal medium-term. Furthermore, industry is also intent on practising economy and re-usage. The pressure of surplus production has been seriously affecting the vegetable-product markets since the early 1980s; alternative production and usage of vegetable raw materials are one possibility for exploiting surpluses and providing farmers with alternative sources of income.

One day, with the help of biotechnology and genetic engineering, it will not only be possible to increase the productivity of food plants. The conversion process of renewable raw materials into basic chemicals or energy carriers could also be decisively improved and the spectrum of convertible substances extended; one only has to think of synthetics from starch or sugar, for example. The fossil sources, which are limited and will become more expensive in future, will be spared somewhat through the employment of regrowable raw materials. At the same time, industry will become less affected by price fluctuations and crises on the international raw materials markets.

Last but not least, even now, non-pollutive, industrial, raw materials and fuels can be produced from renewable raw materials in many cases. Well-known examples, which, mainly for reasons of cost, have still not been able to establish them-

selves, are synthetics from polyhydroxy butyric acid (PHB), which are produced from sugar bacteria, mineralized synthetics and foil from starch, lubricants from vegetable oils, and textiles from natural fibres.

Regrowing raw materials have still not experienced a major breakthrough. "The main reason for this," explains Agricultural Minister Kiechle, "is the fact that the competitive products they are to replace - in other words, fossil raw materials - are relatively cheap at the moment. This particularly applies to the energy sector. Whether this profitability calculation - vis-à-vis the full costs which include environmental costs - is true in all cases, remains to be seen for the moment. Whatever the case may be, the professional world is convinced that renewable raw materials will play an increasing role and - medium to long-term - become an integral part of our daily lives."

(IN-Press)

9. Important addresses

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